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Superfluidity and coherence in fermionic quantum gases

Frictionless flow is one of the most striking macroscopic phenomena arising from quantum physics. Its appearance is remarkably widespread, ranging from superconductivity in solids to superfluidity in liquids and dilute gases. In this colloquium, I will present experiments in which we take the chance to study the stability and coherence of superfluids in experimental model systems, ultracold Fermi gases. In the first part, I will focus on the stability against external perturbations. The corresponding quantity, the critical velocity, is typically highest in the strongly interacting regime. I will show how we can determine the critical velocity in this regime and study its evolution in the crossover from Bose-Einstein condensation to Bardeen-Cooper-Schrieffer superfluidity.

Superfluidity and coherence are intimately connected. In 3D systems, bosonic atoms or Cooper pairs condense into a macroscopic wavefunction exhibiting true long range coherence. Meanwhile, 2D superfluids show a strikingly different behavior: True long-range coherence is precluded by thermal fluctuations, nevertheless Berezinskii-Kosterlitz-Thouless (BKT) theory predicts that 2D systems can still become superfluid. However, the first order correlation function g1(r) decays algebraically with distance with a temperature-dependent scaling exponent tau. I will present local coherence measurements of a strongly interacting 2D gases. They allow us to observe this algebraic, scale-free decay. We can determine the scaling exponent and the superfluid density as a function of phase space density.